

P and S Wave Velocities of Mantle Perovskites to 9 GPa and 873 K

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Introduction: Perovskite is believed to be the most dominant phases present in the Earth's lower mantle in all proposed compositional models. Therefore, knowing the physical properties of this phase is crucial in justifying and distinguishing compositional models as well as understanding the dynamics and the structure of the Earth's interior.

Methods and Materials: We carried out elastic wave velocity measurements on a polycrystalline sample of MgSiO_3 perovskite using ultrasonic Interferometry in conjunction with X-ray diffraction. The experiment was performed in a DIA-type cubic anvil apparatus (SAM85) installed at the superwiggler beamline X17B1 at NSLS in Brookhaven National Laboratory. A dual mode Lithium Niobate transducer (10 degree Y-cut, 30 MHz for S wave and 50 MHz for P wave) mounted at the back of the WC anvil enabled us to collect travel time data for both P and S waves in a single experiment. Cubic boron epoxy cube (6.15 mm edge length) was used as pressure medium. The sample was placed in the center of the boron epoxy cube with NaCl and BN as surrounding materials. A glass buffer rod was inserted into the cell assembly between the WC anvil and the sample with gold foils (2 micron thickness) placed at the interface between sample and buffer rod as well as at the buffer rod and WC anvil interface to enhance the mechanical coupling. The sample pressure was determined using Decker pressure scale from the X-ray diffraction data for NaCl.

The polycrystalline MgSiO_3 perovskite sample used in this study was hot-pressed using USSA-2000 high pressure apparatus at Stony Brook high pressure laboratory. It has 0.875 mm in thickness and about 1.6 mm in diameter after final polishing for acoustic experiment. The specimen has good acoustic quality for bench-top velocity measurements for both P and S waves.

Results: P and S wave travel times were measured to 9 GPa and 873 Kelvin. In the course of high pressure experiment, pressure, sample volume, compressional and shear wave velocities, and temperature (P-V-Vp-Vs-T) were measured simultaneously along heating/cooling cycles at 8.5, 7.3, 5.8, 4.0, and 2.2 GPa after reaching designated peak P-T condition. Travel times for both P and S waves exhibit systematic decrease with increasing of pressure and increase with increasing temperature. The sample length at high pressure and high temperatures were obtained from sample volumes ($l/l_0 = (V/V_0)^{1/3}$). P and S wave velocities calculated from the measured travel times and sample lengths are used to obtain the elastic bulk and shear moduli. P-V-T analysis using high temperature Birch-Murnaghan Eos yielded information of the bulk modulus and its pressure and temperature derivatives. Fitting of the acoustic data with first order pressure and temperature derivatives, we obtained the following results, $K_0=250$ GPa, $K'=5.2$, $dK/dT=-0.025$ GPa/K for bulk modulus, $G_0=170$ GPa, $G'=2.3$ and $dG/dT=-0.028$ GPa/K for shear modulus. These results are 3-4 % lower than previous K_0 and G_0 from Brillouin scattering measurements, and 30% higher than previous dK/dP estimated from P-V-T studies.

Conclusions: We have measured the elastic P and S wave velocities of MgSiO_3 perovskite to 9 GPa and 873 Kelvin using polycrystalline sample in a DIA-type high pressure apparatus at X17B1, NSLS at Brookhaven National Lab. These results are important for the understanding of the composition of the lower mantle when compared with seismic studies.

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